Worldwide Dam Safety review & ICOLD action plan for Dam Safety management.

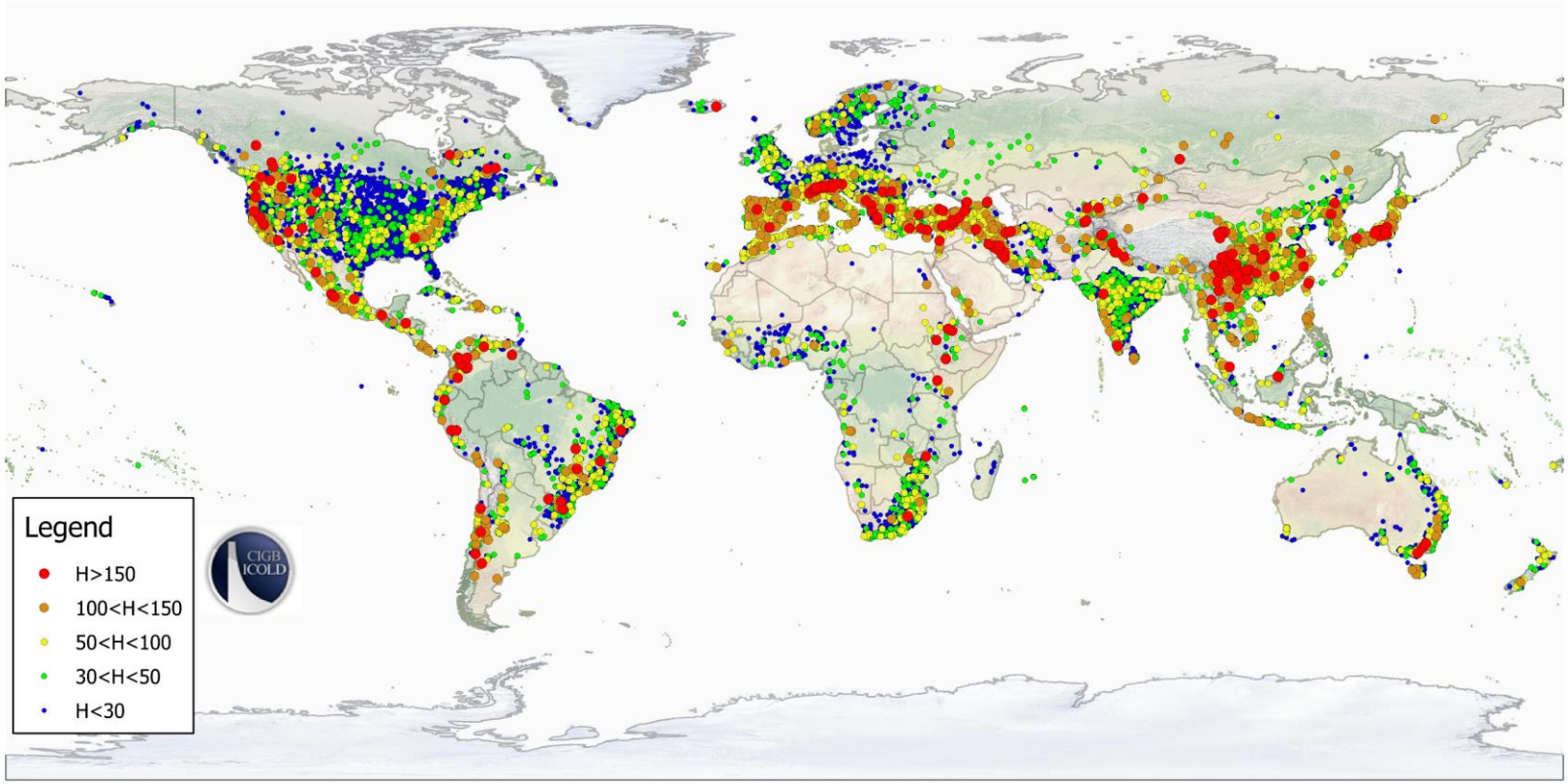
Michel LINO
President, International Commission on Large Dams

CIGB ICOLD

ISL Ingénierie

INTERNATIONAL DAM SAFETY CONFERENCE

Worldwide Dams - More than 58,500 Large Dams in the ICOLD Register



INCOLD
Indian National Committee on Large Dams

INTERNATIONAL DAM SAFETY CONFERENCE

DRIP
Dam Rehabilitation & Improvement Project

Central Water Commission

Dams are important and unique INFRASTRUCTURE

WATER

ENERGY

FLOOD CONTROL

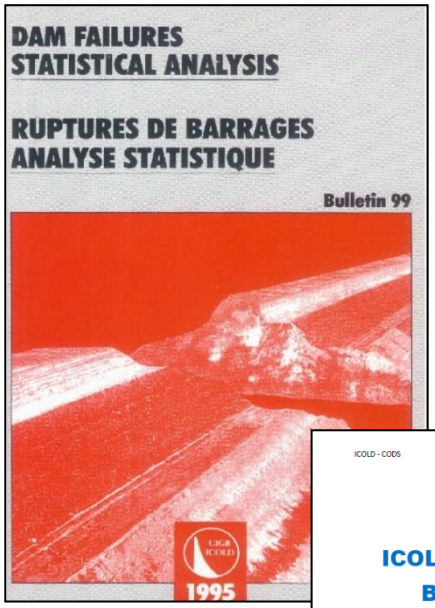
CIGB ICOLD

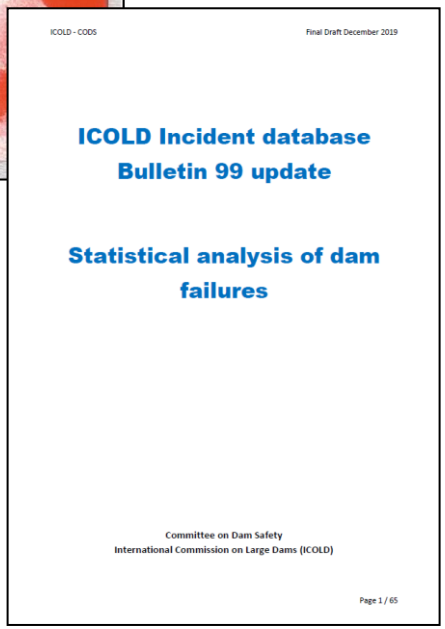
10-12 October 2022 at Jaipur, Rajasthan (India)

Dam failures and incidents Database

- **It is widely recognized that engineering failures and incidents provide valuable lessons and advance the state of the practice.**
- For many years, ICOLD has developed and maintained a dam incident database.
- In 2021, ICOLD bulletin 99 was updated (322 cases included).

- **In a significant development,iIn Sept. 2022, the ICOLD Board decided to make the database accessible on the ICOLD web site.**





- ICOLD has played a key role in the highly significant improvement of dam safety ☺

ICOLD Bulletin 188

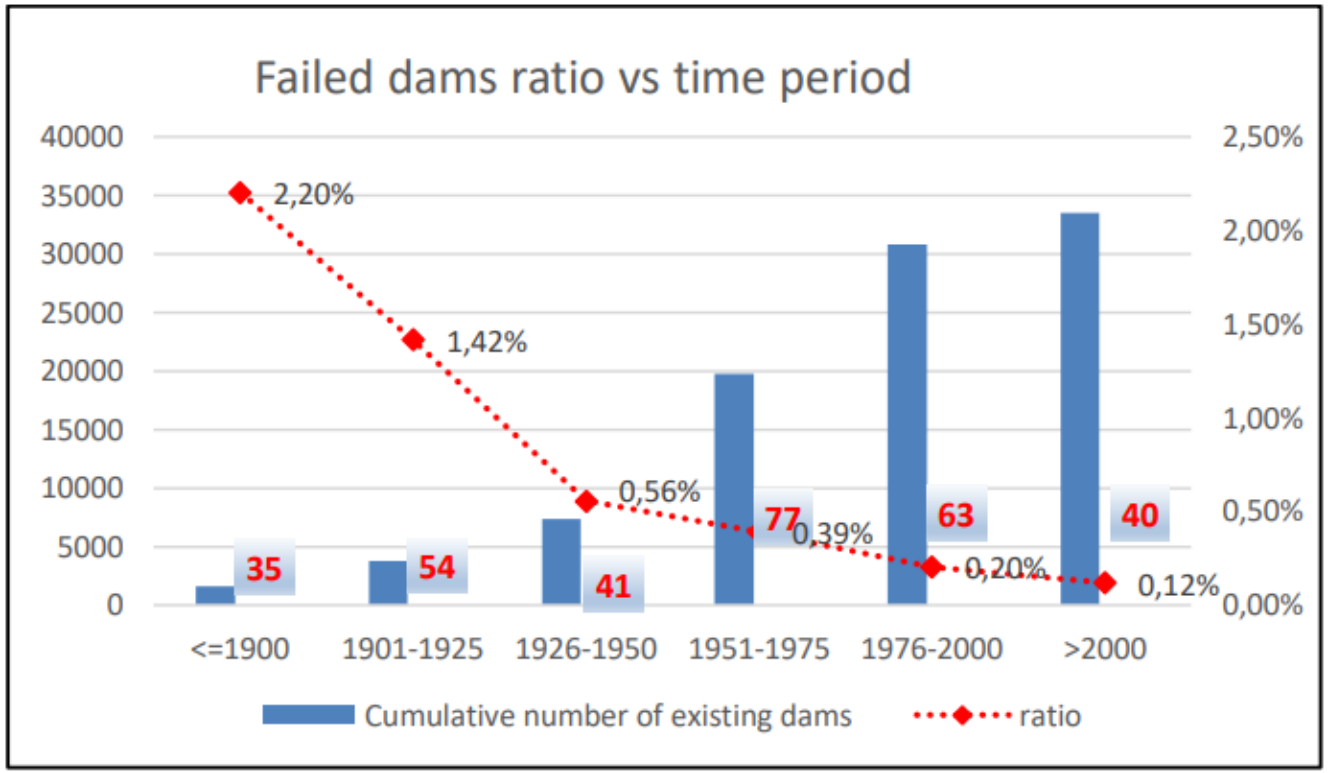
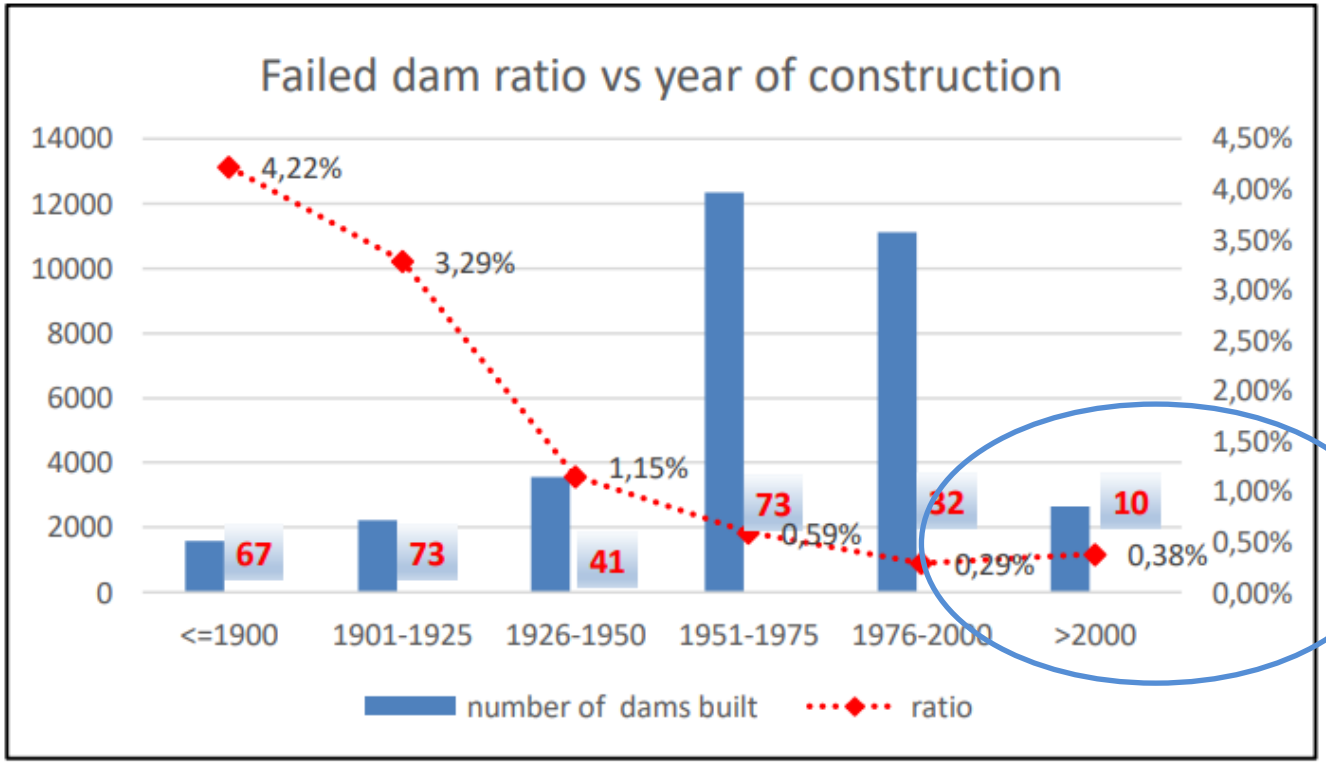


Figure 3-1 : Dam failures by time periods and ratio with existing dams

- However, the failure ratio **versus age of construction** increases after 2000…☹

ICOLD Bulletin 188



What is the significance of this statistics?

Some significant cases

TOKWE MUKOSI Zimbabwe - 2014

Failure/incident at a young age

90 m high CFRD
C = 1.75 billion m3

Reservoir filled up without upstream facing

Cause:
Diversion tunnel undersized

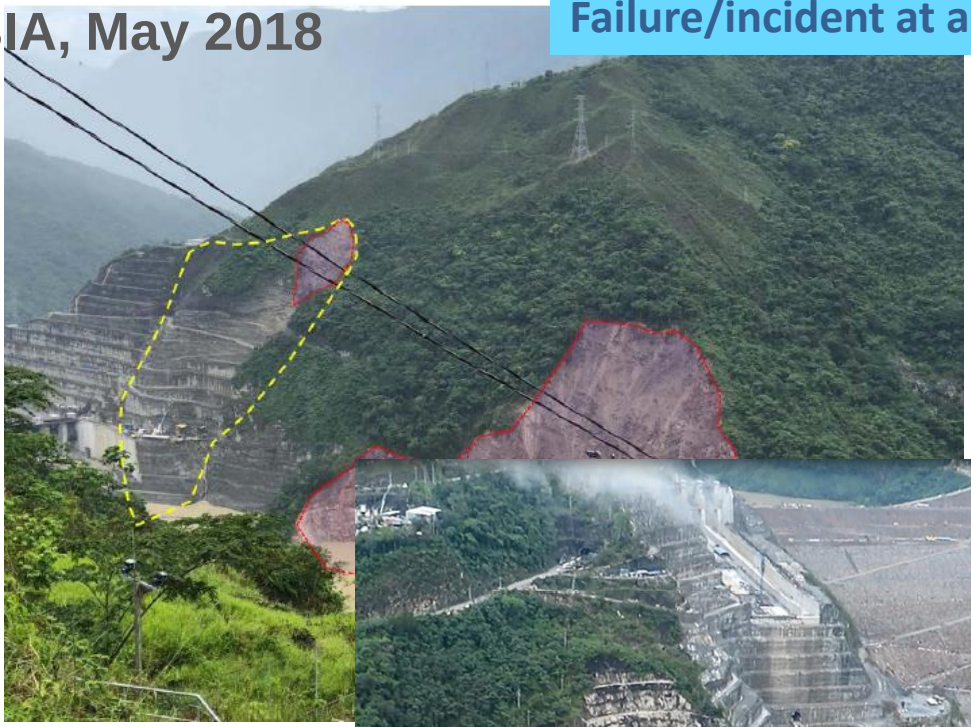
No failure…

ITUANGO dam- COLOMBIA, May 2018

Failure/incident at a young age

Central Core Rockfill Dam
227 m high
C = 2,7 billions m^3

- The diversion tunnel was blocked by a landslide and fontis **near the end of construction.**
- Uncontrolled raising of the reservoir level.



Discharge by the power plant cavern ≈1000 m3/s under 200 m head!!!

ITUANGO dam- COLOMBIA, May 2018

Failure/incident at a young age

Speed race between the rise of reservoir (100 m in a few days) and the rise of the emergency upstream embankment ...

Finally, the dam was saved

Xe Pian - Xe Namnoy – Laos, July 2018

Failure/incident at a young age

Failure of saddle dam of a large hydroelectric scheme **during first filling**

- Homogeneous dike - H= 16 m
- On 16 m lateritic foundation
- no foundation treatment

✓ Abnormal settlements recorded before failure

✓ No overtopping

→ **Cause of failure : regressive erosion in the pervious and erodible lateritic foundation**

Xe Pian – Xe Namnoy – Laos, July 2018

Failure/incident at a young age

Total volume of the Xe Namnoy reservoir : 1 billion m^3

Volume released : 0,5 billion m^3

140 casualties

More than 12 000 affected people

Sardoba dam (Ouzbekistan) – May 2020

Failure/incident at a young age

Dam

Embankment dam
Commissioning : *2017*
Height : 29 m
Volume reservoir : ≈ 922 Mm3
Failure during flood

Consequences :

Transboundary issues
Few casualties
Inundation and damages

Emergency plan

70 000 p evacuated in Ouzbekistan
20 000 p evacuated in Kazakhstan

- The 4 previous cases concern **modern major dams**
- Incidents or failure occured during construction, first filling or few years after commissionning…

What is going wrong?

What can we do to improve the situation?

The following cases are related to another very important failure context :

- **Failure during flood**
- **Increased risk due to Climate Change**

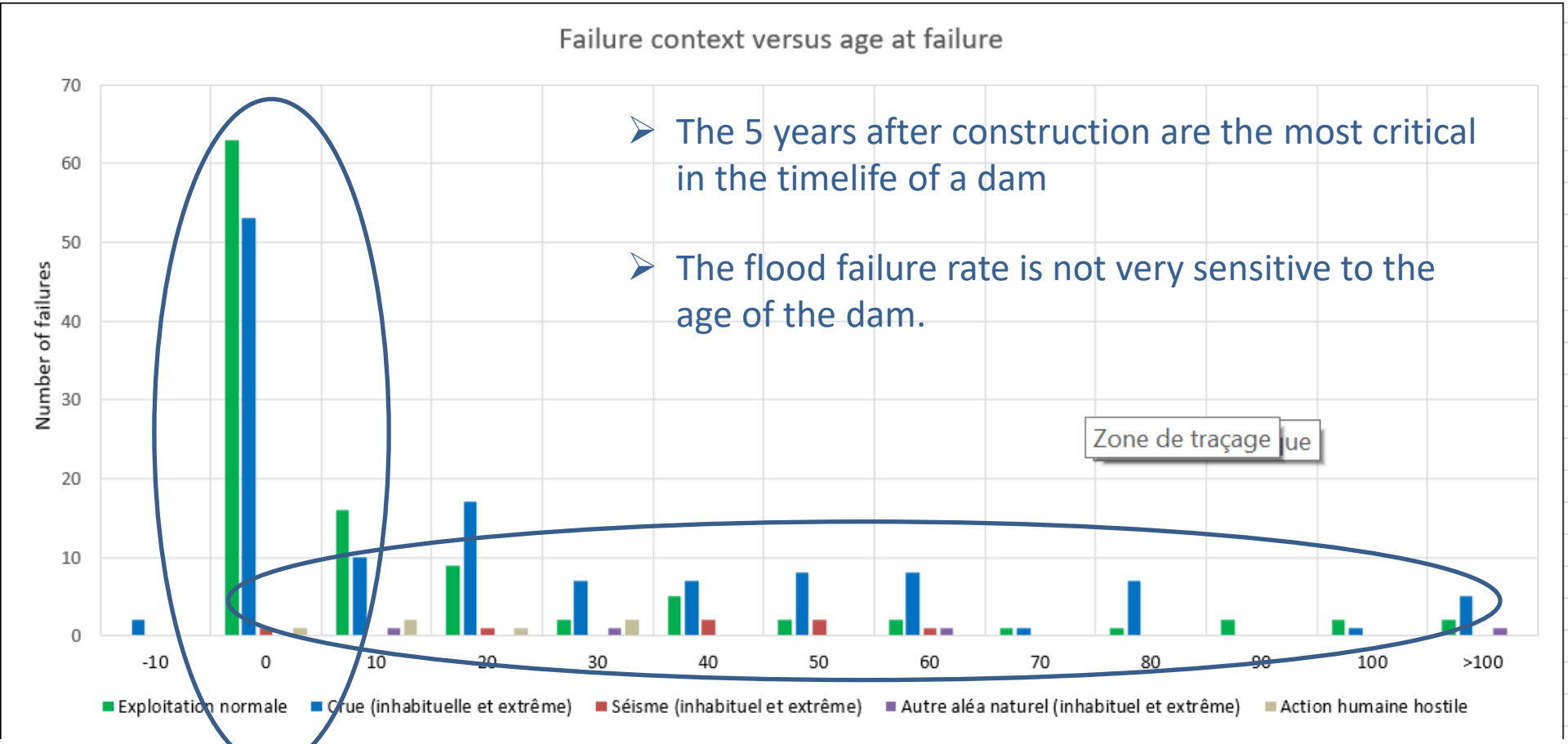
Failure during flood

Edenville dam – USA (May 2020)

Xinfa dam (China) failure by overtopping (July 2021)

Igua dam – Brazil (December 2021)

Annamayya dam – India (November 2021)



- The 5 years after construction are the most critical in the timelife of a dam
- The flood failure rate is not very sensitive to the age of the dam.

World Declaration on Dam Safety

- ICOLD Mission statement says

  "ICOLD leads the profession in setting standards and establishing guidelines to ensure that ***dams are built and operated safely****, efficiently, economically, and are environmentally sustainable and socially equitable."*
- Core value of ICOLD since its foundation in 1928
- ICOLD issued in 2019 a World Declaration on Dam Safety

World declaration on
Dam Safety

The construction, operation and maintenance of dams and their storage reservoirs have provided significant benefits to humankind throughout history. Storage of water behind dams regulates natural streamflow, provides benefits resulting from increased water availability, renewable energy production and reduction of adverse impacts caused by nature's extremes of flooding and drought. This document addresses the importance of the dam safety, which encompasses water dams, mining tailings dams and levees.

Growing population in our fragile world is causing steady increases in demand for water, food, energy, minerals and flood control. **Dams are critical infrastructure to meet these basic human needs as well as rising standards of living.** At the same time, however, dams create new hazards involving potential risks to downstream communities, including potential adverse impacts on life, property and the environment. The potential for dam safety incidents, possibly resulting in an uncontrolled or catastrophic release of stored water is of the highest concern.

The profession of dam engineering has a profound ethical responsibility to carry out its professional duties so that dams and reservoirs are designed, constructed and operated in the most effective and sustainable way, while also ensuring that both new and existing dams are safe during their entire lifespan, from construction to decommissioning.

ICOLD and Dam Safety

For almost a century, the International Commission on Large Dams (ICOLD) has made dam safety one of its highest organizational commitments, as stated in the ICOLD Mission statement:

«ICOLD leads the profession in setting standards and establishing guidelines to ensure that dams are built and operated safely, efficiently, economically, and are environmentally sustainable and socially equitable.»

Before the creation of ICOLD in 1928, knowledge on dam safety was disparate, while the need for building water storage infrastructure was very high and growing. It therefore became a priority of ICOLD to disseminate the understanding of the design and operation of dams based on experience within the global dam engineering community. And along with this dissemination came a strong focus on dam safety that has permeated up to the modern era.

ICOLD has played a key role in improving dam safety through its work in collecting and analyzing information on the lessons learned from past successes and failures. Since the very beginning, ICOLD and its thousands of professionals within the member countries have continuously contributed to the improvement of dam safety through publication of technical papers and exchange of experience during Annual Meetings and Congresses. ICOLD's Technical Committees develop Bulletins for publication that summarize the current state of the practice.

Since the creation of ICOLD, the number of failures compared to the total number of dams in operation has been reduced significantly, which is a positive achievement that reflects the worldwide influence of ICOLD in raising dam design and management standards. Nonetheless, constant vigilance and commitment to dam safety is still required in order to continue the global trend towards safer dams. Any dam incident is a matter of the gravest concern for dam professionals. **It is our ICOLD Declaration that Dam Safety is our highest priority.**

Changing Conditions of Dam Safety

Due to the vital need for water, food, energy, minerals and flood control, the total number of dams worldwide continues to grow. Maintaining the present trend of a decreasing incidence of dam failure is a never-ending challenge for the profession. ICOLD's role in knowledge transfer and capacity building through the dissemination of the best practices is as pertinent as ever. The science, technology and human roles in dam safety are in constant evolution with many changing conditions:

- **Aging of existing infrastructure,** creating new concerns related to the longevity of construction materials and equipment, including infilling of reservoirs with sedimentation.
- **Lack of experience in dam safety management and operations** in some countries engaged in building dams, requiring the need for capacity building.
- **Retirement of experienced personnel** in all countries, leading to a deficiency in qualified engineers trained in dam design.
- **Increasing participation of the private sector** in the development of dams as well as increasing cost and time pressure on developers, designers, contractors and operators, creating a need for new governance conditions for dam safety.
- **Climate change causes changes in extreme precipitation** and drought events, resulting in increased hydrological risks. It is critical to consider changes in climate during planning and management, including resilient design and adaptive reservoir operation of dams. In some regions, this results in a need to increase the height of dams, expand spillway capacity, modify reservoir operating procedures, and/or construct new dams. There may also be a need to assess and address other hazards created by climate change as part of the planning, design and operational phases.
- **The most suitable sites for dams have largely been utilized,** thus new dams must be built in more and more challenging locations, especially regarding geological conditions.
- **Changing local, regional and national governance** can have a significant impact in regulatory authority for dams.

As a recognized international organization of experts in dam engineering, ICOLD calls upon governmental authorities and financing institutions to promote an awareness of the subject of Dam Safety. **The goal of this ICOLD World declaration on Dam Safety is to restate the fundamentals of dam safety** that have been learned over time. Furthermore, all involved entities should be reminded to ensure, through the fulfillment of their responsibilities, that these fundamentals are respected in order to minimize risks associated with dams and reservoirs.

Pillars of Dam Safety

With almost a century of commitment to dam safety, and knowing that the zero risk does not exist, ICOLD recognizes several overarching pillars of dam safety:

- **Structural integrity of dams is the keystone to dam safety.** Best current practices of dam design and performance during the occurrence of hazardous events such as extreme floods and earthquakes have been largely documented by ICOLD bulletins in order to create a sound basis on which existing and future dam structures should be designed, built and operated in safe conditions.
- **A routine surveillance and maintenance programme is necessary for early detection.** Inspection and upkeep are of high importance to minimize the risk and to ensure dam safety in the long term. Periodic safety review by qualified engineers that are highly experienced in dam safety assessment is mandatory. Supervision of dams should be based on both the operator's self-supervision and periodic external safety reviews by an independent and competent authority or institution.
- **An instrumentation and monitoring programme is essential throughout the life of a dam.** A comprehensive dam monitoring programme is necessary to: a) determine behavior during construction; b) assess performance during first reservoir filling; c) compare actual performance with design; d) characterize long-term behavior; e) provide early warning of abnormal conditions; f) capture & analyze response to events, such as large floods, earthquakes, etc.; g) predict future performance of dam; and h) demonstrate safe management of the dam to regulatory authorities.
- **Design-Intrinsic risks need to be adequately addressed.** These risks are based on dam type, materials, ageing, foundations, hydraulic structures, etc., in which good practices and surveillance are the keys for safety.
- **Natural hazard risks change with time, thus should be regularly reviewed and updated.** These hazard risks like floods and earthquakes are external threats, for which risks are accepted based on known science and likelihood of occurrence.
- **Emergency planning is of utmost importance for all dams.** Emergency plans should be developed with the objective of avoiding loss of life and reducing damage to property, infrastructure and the environment resulting from a dam failure. The first filling of the reservoir being a critical period during which the emergency plan must be ready for implementation in a timely manner. Periodic review, updates and practice of the emergency plan is mandatory.
- **Adequate training of operators is part of a comprehensive dam safety programme.** Those placed in charge of dams bear an important responsibility to maintain their training and understanding of their dam. Mis-operation of a dam, especially of spillway gates, can lead to accidents, downstream flooding or potential overtopping of the dam.
- **Sharing lessons learned benefits the entire industry, making all dams safer.** The experience of ICOLD has shown that sharing lessons from dam incidents and failures is crucial to improve state-of-the-art practices. For all involved parties, it is thus imperative that any documentation on dam incidents, including independent expert reports on the root causes of such incidents, be made freely accessible to the international community.
- **A comprehensive dam safety approach will allow minimization of risks.** This is done through collaboration of national organizations to support dam safety: structural measures for strengthening the structure's integrity and stability; measures to minimize the consequences of failures as well as education and public awareness about dams. A comprehensive dam safety approach should also consider the fact that river basins, many of which are transboundary basins, often include several dams, or systems of dams and levees.
- **A dam owner has the ultimate responsibility for its dam.** ICOLD recognizes that the safety of all dams is primarily the responsibility and liability of owners and operators. Adequate personnel and financial resources as well as relevant know-how are essential conditions to meet this responsibility.
- **The role of regulatory authorities is paramount for safety.** Regulatory authorities should take a strong role in ensuring adequate site investigation, best practice design standards, quality construction, contractual frameworks, emergency preparedness and operational compliance within accepted guidelines and standards. Developing norms, standards and safeguards is a key factor to proper dam safety surveillance.
- **An international perspective to dam safety can be enlightening.** International organizations such as ICOLD, which provide guidelines based on worldwide experience, can provide important guidance to designers, owners and government authorities to better understand the current state of best practices for design and safety of dams.

Summary Declaration

With the aspirational goal of working towards continuous reduction of dam safety incidents, ICOLD, as the leading international organization committed to dam safety, calls upon **all involved professionals and companies to make a firm commitment to safety improvements and risk reductions at all dams.**

Furthermore, **Governments, Financial Institutions and other Developers, in their contribution to the development and regulation of dam infrastructure, are called upon to make a similar political and financial commitment** so that the all-important safety recommendations for dams outlined in ICOLD Bulletins, will be disseminated to the relevant entities and followed to completion.

This common effort will contribute immeasurably to the overarching ICOLD vision:

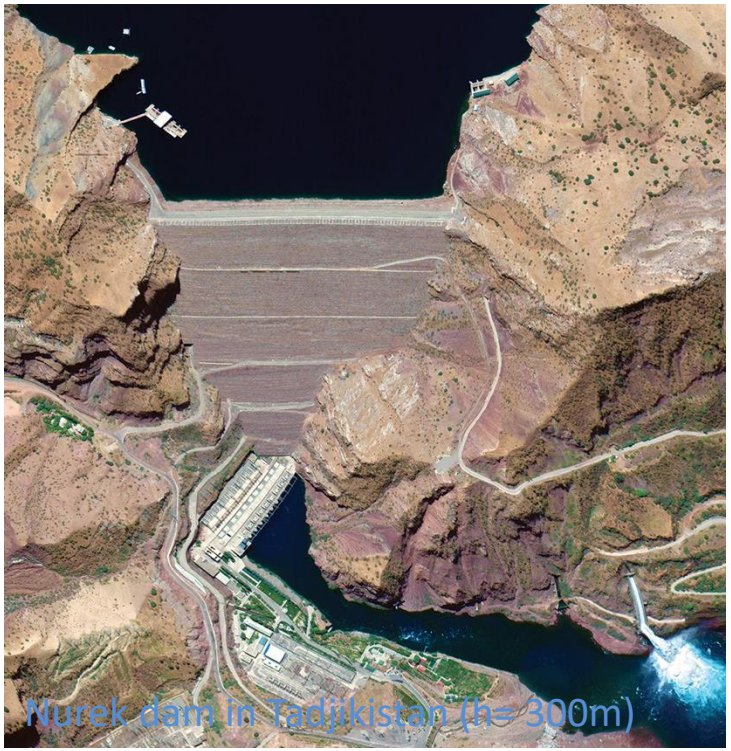
"Better Dams for a Better World"

Approved on October 18th 2019, in Porto.
International Commission On Large Dams

World Declaration on Dam Safety

Pillars of Dam Safety (1)

- Structural safety
  - Normal operation and extreme conditions
  - ICOLD bulletin
- Vigilance in surveillance and monitoring
  - Understanding the performance of the dam
- Emergency planning

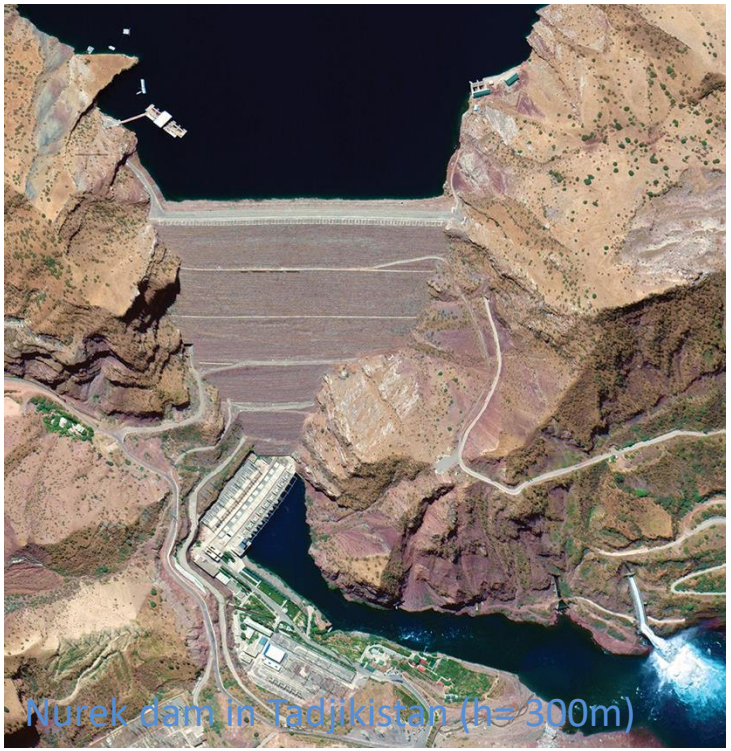


Nurek dam in Tadjikistan (h= 300m)

World Declaration on Dam Safety

Pillars of Dam Safety (2)

- Sharing Lessons - Success and Failures
- National Governance is essential
- Owner Responsibility
- Risk Informed Decision Making



Nurek dam in Tadjikistan (h= 300m)

World Declaration on Dam Safety

Main principles and issues

- Safety criteria of Existing Dams – Same as New Dams
- Safety of Tailings Dams and Mining Dams – Same Criteria as Water Dams
- Safety of Systems – cascades, transboundary jurisdiction's, etc.
- Reservoir Sedimentation
- Climate Change Impacts
- Regular Operation and Maintenance

World Declaration on Dam Safety

Changing Conditions of Dam Safety

- The ageing of existing infrastructure : UNU report - 2021
- More and more emerging and developing countries are now building dams, but they may lack experience in dam safety management.
- The increasing participation of the private sector in the dam business creates new governance conditions for dam safety.
- Climate change creates new natural hazards (flood, drought, typhons…)
- New dams must be built in more and more challenging sites, especially regarding geological conditions.

World Declaration on Dam Safety

ICOLD action plan for Dam Safety

- Dissemination of the World Declaration on DS
- Pedagogic presentation of the WDDS to be provided to the National Committees
- Dissemination of information of dam failures and incidents (Database on ICOLD web site)
- Capacity building enhancement in partnership with International organisation, Develpment Banks, etc…
- Promotion of Dam Safety Panels for new dam projects and rehabilitation projects
- ICOLD List of Certified Experts under study

Key messages

- Dam Safety is a core value to ICOLD
- Dam Safety relies on a strong National Governance
- Dam safety is a personal duty and a sacred responsibility to the dam engineers
- Failures and incidents provide valuable lessons and advance
- Dam safety management is a daily activity and a long-term commitment for many generations


Thank you for attention